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(54) **Improvements to the ceramic nozzle flame outlets for welding plugs onto nuclear fuel rods, the manufacturing process for the rods and their corresponding plugs**

(57) The invention refers to the optimization of the laminar flow produced at the outlet of a flame (1), by a double ceramic nozzle (3-9) for welding, specifically applicable to weld plugs to the corresponding ends of the pipes forming the fuel rods in nuclear reactors, the welding being performed by an electric arc jumping from a tungsten electrode (6) to the object to be welded, inside a tight chamber full of inert gas. The use of this double nozzle (3-9) allows welding at a high inert gas pressure, hence eliminating the sealing phase required in the production processes of nuclear fuel rods.

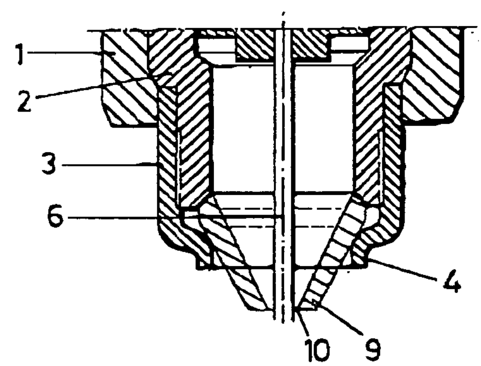


FIG.-4

EP 0 869 512 A1

Description

OBJECT OF THE INVENTION

The invention refers to a series of improvements introduced in the flames used in welding with tungsten electrodes, for fixing plugs over nuclear fuel rods. Said improvements consist of the use of a double ceramic nozzle optimizing the laminar flow incorporated to the flame to permit high pressure welding.

The flame together with the nozzle, and, naturally, the electrode to execute welding, is especially applicable to any kind of process involving TIG welding, namely, those based on tungsten electrodes. Although, particularly, the flame herein described has a specific application in the field of cap welding to Zircaloy pipes without sealing boreholes for the preparation of fuel element rods used in nuclear reactors.

The invention also provides the production process for these fuel element rods, and even the characteristics of the plugs themselves, since the application of high-pressure welding influences the different production process stages of said rods and plugs, as well as in the corresponding inspections.

BACKGROUND TO THE INVENTION

A vessel corresponding to a nuclear reactor includes several fuel assemblies, each one consisting of a number of nuclear fuel rods specifically containing enriched UO_2 pellets or other radioactive oxides or a mixture thereof comprising the active material.

The aforementioned rods consist of Zircaloy pipes filled with fuel pellets, retainer and absorbent assemblies, to which two plugs of the same material are welded at their ends.

Now then, the type of welding used to join the pipe with the plugs is that known as TIG, consisting of an electric arc that jumps from a tungsten electrode to the object to be welded, inside a tight chamber full of inert gas (normally helium and/or argon). The latter is performed such that the arc melts the pipe-cap joint area, whilst the latter rotates.

The tungsten electrode used in welding consists of a narrow tungsten alloy cylinder of different diameters, those of 1 and 1.5 mm diametre being more commonly used to prepare fuel rods, the electrode being fixed by a flame that should be equipped with a welding point and an inert gas inlet and whose purpose is to cool the electrode and maintain an inert atmosphere where combustion is not possible.

On the other hand, the end of the electrode where the arc jumps should be free and surrounded by a flow during welding to prevent its combustion and facilitate heat exchange. Traditionally, when welding at low pressure (slightly greater than atmospheric pressure), a single ceramic nozzle has been used to direct said flow, thought to be more suitable for laminar type heat exchange. However, at high pressures, small changes of section in the flame will produce eddy flows.

When inspecting welding, two types of inspection may be used, the so-called destructive one (metallographic analysis) or the non-destructive one (ultrasonic or X-ray inspection), such that if the destructive test is used, by performing longitudinal metallography and attack, the weld bead or melted pipe-cap area may be observed, said weld bead having a semi-elliptical configuration, such that the major axis of the ellipse is called "bead width", whilst the minor semi-axis is called "radial penetration". The ratio between radial penetration and bead width is known as weld litheness, this being one of its quality characteristics.

Moreover, it is necessary that the gap left by the pellets within the pipe is filled with inert gas (the same as that used in welding) pressurized between 10 kg/cm^2 (BWR) and 30 kg/cm^2 (PRW). Until now, the state-of-the-art has not allowed circular welds to be performed directly at said pressure values, such that the use of better plugs with a hole has been resorted to, allowing the can to be pressurized and hermetically sealed at a later production stage.

DESCRIPTION OF THE INVENTION

The purpose of the invention is to eliminate the sealing and inspection stages to be executed as a result of the sealing stage performed conventionally, as well as those of the nuclear fuel rod production and plug manufacture and forming processes. For this reason, it is necessary to weld plugs with a hooped design at high pressures.

Moreover, to perform high pressure welding and with hooped designed plugs, it is necessary to use a double nozzle optimizing the laminar flow at the gas outlet through the flame, such that this double nozzle permits specific heat concentration, increasing weld litheness, a necessary requirement when welding at high pressure, since if melting occurs outside the hooped area, melt down and blow down problems occur.

As a result, the use of laminar flow at the flame outlet favours heat exchange in the welds, such that by working at high pressures, this flow may be optimized by a double nozzle set which, in turn, concentrates the heat and increases their litheness.

The concentrated laminar flow will permit high pressure welding and the simplification of the nuclear fuel element or rod production process, the result of the latter being that hooped plugs may be used without a sealing borehole, besides eliminating the sealing stage and corresponding welding inspections, in that way gaining in productivity and cheapening the product.

Besides, as a result of that expressed above, two production phases will be modified, one corresponding to the simplification of the rod and plug production process, as well as the change of stages in the second weld-

ing, and another corresponding to the elimination of the phases required in conventional processes, corresponding to the suppression of the pressurization and sealing stages, the sealing inspections and the radiographic sealing inspection.

Definitively, the flame made according to the improvements of the invention, that is, equipping with the double ceramic nozzle, allows gas flow to be optimized and concentrated on the area to be welded, permitting high pressure welding between 10 and 30 kg/cm^2, which is possible thanks to the optimization of concentrated laminar flow and the use of borehole-free hooped plugs.

DESCRIPTION OF THE DRAWINGS

To complement the description being made and for a better understanding thereof, this specification is accompanied by a set of drawings, to illustrate but in no way limit it, as follows:

Figure 1.- This represents a section corresponding to the lower end of a welding flame with a conventional nozzle, it being possible to see the raised opening at its outlet, as well as the section changes in the area where the nozzle joins the flame approach axis. Obviously, when working at low pressures, this change of section is irrelevant. However, this is not the case at high pressures, since said section changes would imply sudden changes in flow speed with the ensuing production of eddy flows.

Figure 2.- Shows a side elevation view with a quarter section and a plan view of a nozzle used traditionally.

Figure 3.- Shows a side elevational view with a quarter section and a plan view of the second nozzle complementing the traditional nozzle used in the flame and made according to the improvements of the invention.

Figure 4.- Shows the second nozzle adapted over the inside end part of the main nozzle within the assembly comprising the welding flame.

Figure 5.- Shows a side elevational view of the head corresponding to the plug used to weld at a high pressure according to the improvements of the invention.

Figure 6.- Shows the practical application or result of welding the plug represented in the previous figure at a high pressure.

Figure 7.- Shows the diagram corresponding to the nuclear fuel rod production process, based on using flames with double ceramic nozzles to perform welding.

Figure 8.- Shows the production process for the plug shown in figure 5, used for welding at a high pressure.

PREFERABLE EMBODIMENT OF THE INVENTION

As may be observed in the aforementioned figures, and specifically referring to figure 1, a flame generally indicated by the number (1) may be seen, with its corresponding internal body (2) and the ceramic nozzle (3), with its outlet mouth (4), having a considerably wide opening and of a design such that the flow generated should be laminar for pressures near to atmospheric pressure, since changes of section (5) thereof are deemed negligible. Besides the mentioned flame, the corresponding tungsten electrode (6) and its free end (7) may be observed in this same figure 1.

Figure 2 shows a conventional nozzle (3') with an internal screw thread (8) for its assembly and coupling in the flame body (1). This nozzle (3') has a narrow outlet mouth (4').

Now then, according to these conventional features, one of the novelties of the invention consists of using a second nozzle (9) having a tapered configuration, although with a slightly oval contour and with an outlet mouth (10) of a reduced diameter, such that hereinafter this nozzle (9) will be called the "internal nozzle", foreseeing its assembly inside the flame (1), corresponding to the outlet mouth (4) of the nozzle (3). The mentioned internal nozzle (9) being overlapped, as seen in figure 4, which prevents sudden changes of section and, hence, averts the production of eddy flows when working at high pressures. On the other hand, the narrowness of the outlet mouth (10) of the internal nozzle (9), with its special configuration, facilitates heat concentration and welding litheness, since the laminar flow foreseen to perform high pressure welding is perfectly concentrated, which, in turn, allows a simplification of the production process, both of the nuclear fuel rods and the plugs used and which are welded to the ends of the former.

To weld at a high pressure it is necessary that the corresponding plug (11) has a hooped design (12) and a head (13) with a special configuration as shown in figure 5, plugs facilitating the capping of the rods and which allow a pressure difference to be maintained between the interior of said rods and the chamber necessary for said type of welding. On the other hand, and due to the fact that the flow is narrow and turbulent, the area melted in the weld (14) is reduced, such that the bead is narrower than the hooping length (12'), avoiding melting of the area without hooping (15), which would involve problems of melt down and blow up.

The use of flames with a double ceramic nozzle according to that described above, and the possibility of

performing plug welding at a high pressure allows nuclear fuel rods to be obtained by a process more simple than traditional ones, this process including the stages shown in figure 7 and corresponding, from that of rest, to: a first stage to close clamps, followed by a vacuum stage, then a pressurization stage, followed by a capping stage and then a second pressurization stage, being followed by welding and afterwards the corresponding cooling and a final depressurization stage, hence eliminating the conventional pressurization stages, sealing and the pertinent corresponding inspections, besides those already commented in the conventional production processes of fuel rods.

Likewise, the plug used according to that described above and which is welded at a high pressure, at the ends of the nuclear fuel rods, is obtained according to a process which similarly reduces specific stages regarding conventional production systems, namely, the stages of the plug production process consist of: feed roughing, followed by the feeding stage itself, continued by a finishing stage of the tapered part, in turn followed by a contour roughing stage, and then, a finishing stage of the contour itself, then, in a following stage making a longitudinal groove of the plug itself and then a thread, as well as the housing of a spring, the finishing of the corresponding tapered surface, to perform docking and terminating with the plug housing stage in the corresponding pipe forming the relevant nuclear fuel rod.

Claims

1. Improvements to the ceramic nozzle flame outlets for welding plugs onto nuclear fuel rods, which on being applicable to that type of flame used in circular welding processes where a plug is welded on the corresponding ends of nuclear fuel rods, an electric arc which jumps from a tungsten electrode to the object to be welded is used in welding, and where the welding is performed inside a tight chamber filled with inert gas, the flame itself using a ceramic nozzle (3) with a wide outlet mouth (4) and a nozzle (3') with a narrow outlet mouth (4'), characterized in that it includes a second internal nozzle (9) of the same material, having a tronco-conical configuration, with its greater open base overlapping with the end of the internal body (2) of the flame (1), and with the same diameter as the former, whilst the outlet end configures a narrow mouth (10) optimizing the laminar flow of the inert gas concentrating it towards the area to be welded and enabling the performance of high pressure welding.

2. Improvements to the ceramic nozzle flame outlets for welding plugs onto nuclear fuel rods, according to claim 1, characterized in that the pressure at which welding is executed within the tight chamber of inert gas, varies between 10 and 30 kg/cm^2.

3. Nuclear fuel rod manufacturing process, where the rods consist of Zircaloy pipes filled with fuel pellets and closed at their ends by the corresponding caps, fixed by welding at a high pressure, characterized by performing two different pressurization phases and between them, a phase corresponding to the capping of the pipe ends comprising the rods, then carrying out the corresponding welding after the second pressurization phase, afterwards a cooling phase, followed by a final depressurization phase.

4. Plug for closing the ends corresponding to the nuclear fuel rods, foreseen to be fixed by welding to the ends of a nuclear fuel rod and whose welding is performed at a high pressure, characterized in that it consists of a body (11) with a slightly tronco-conical configuration, with no openings, hooping (12) and a head (13) with a special configuration, creating a melted area (14) in the weld, whose corresponding bead is narrower than the hooping length (12').

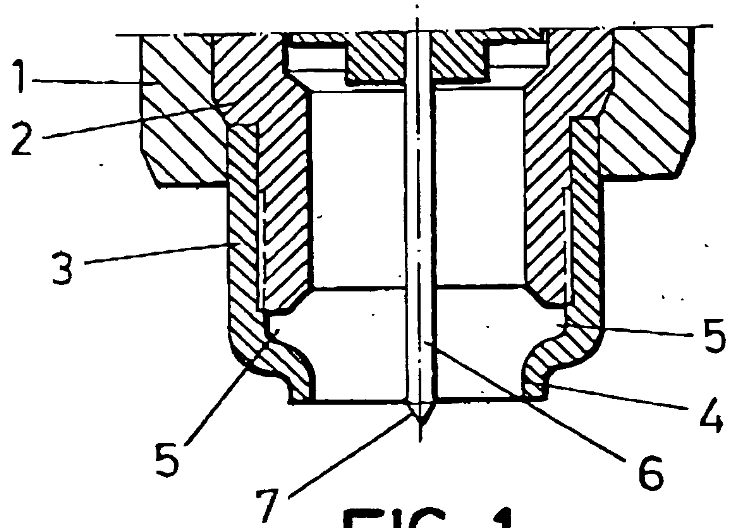


FIG.-1

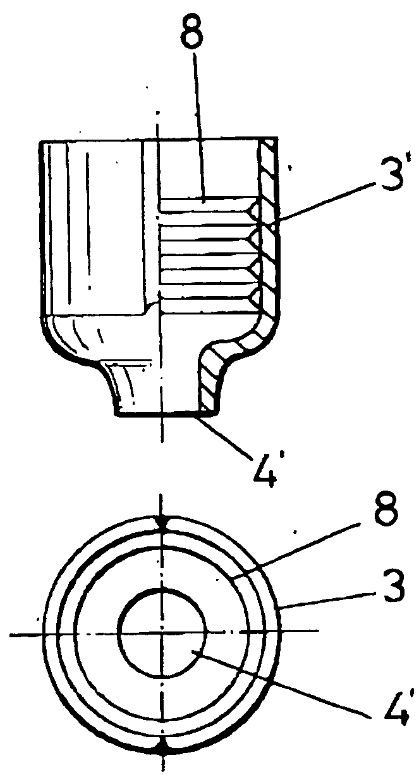


FIG.-2

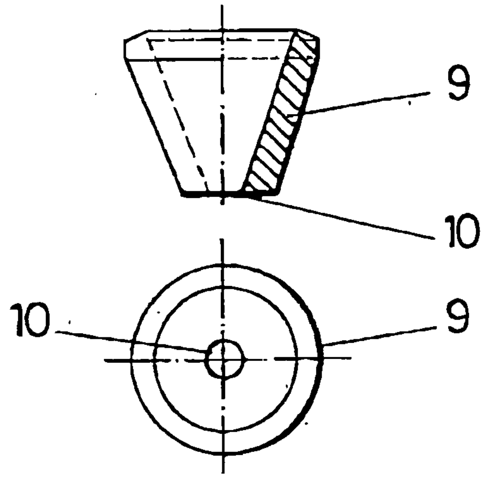


FIG.-3

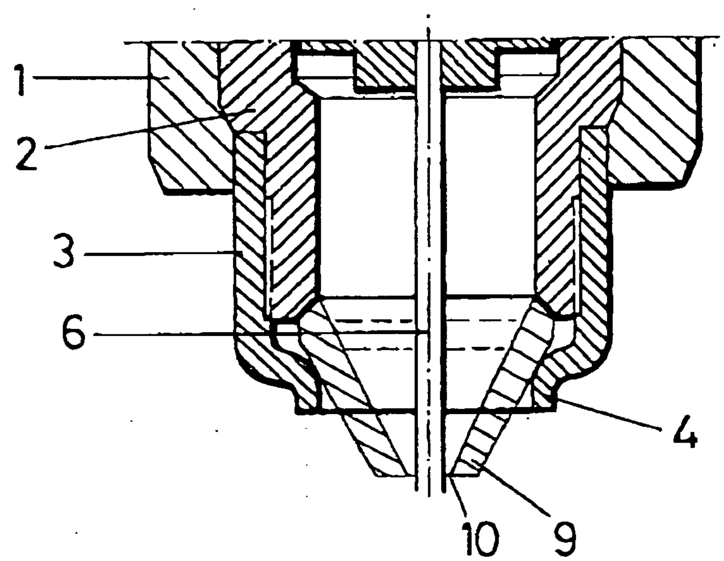


FIG.-4

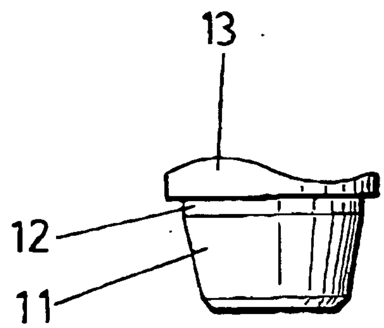


FIG.-5

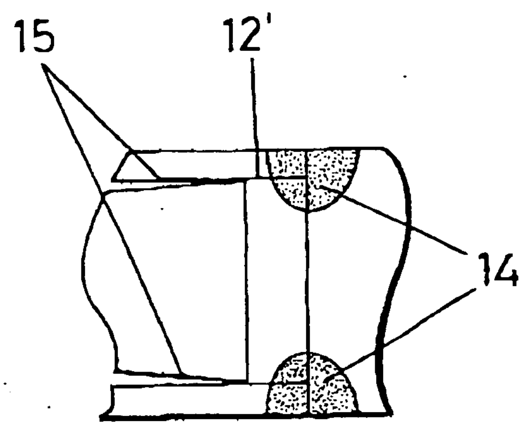


FIG.-6

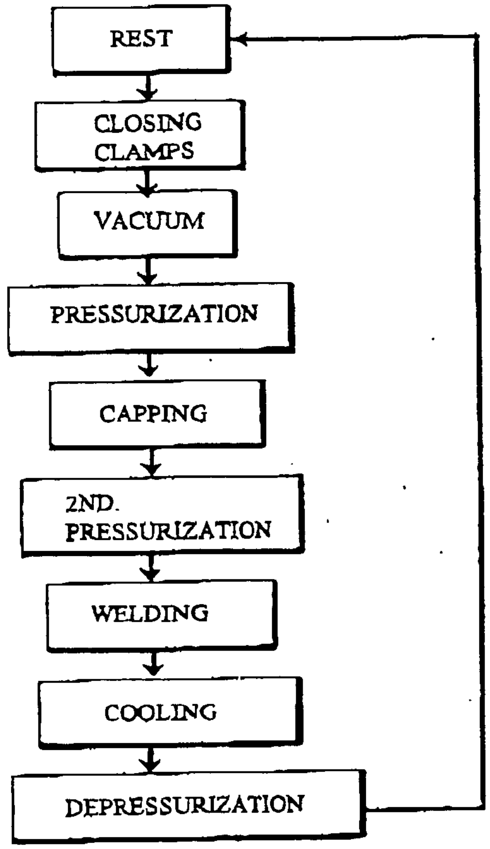
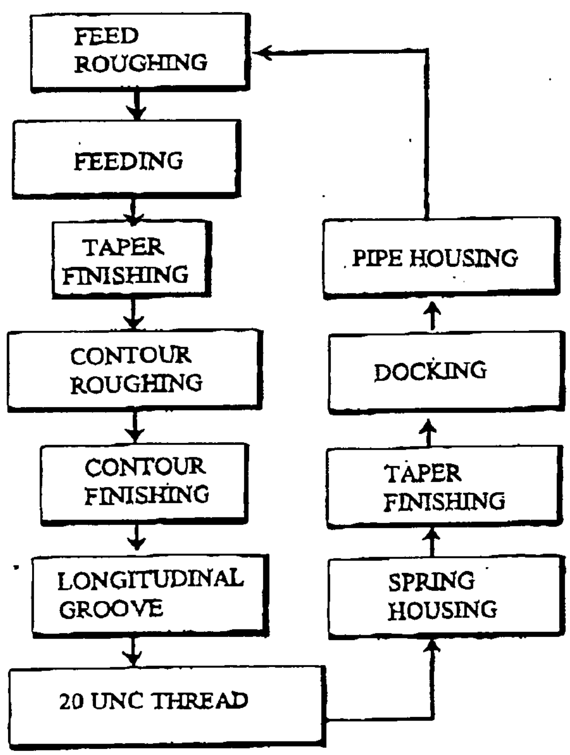

REST
CLOSING CLAMPS
VACUUM
PRESSURIZATION
CAPPING
2ND. PRESSURIZATION
WELDING
COOLING
DEPRESSURIZATION

FIG.-7

FIG.-8


FEED ROUGHING
FEEDING
TAPER FINISHING
CONTOUR ROUGHING
CONTOUR FINISHING
LONGITUDINAL GROOVE
20 UNC THREAD
SPRING HOUSING
TAPER FINISHING
DOCKING
PIPE HOUSING

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 50 0062

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	US 5 124 525 A (SEVERANCE JR WAYNE S ET AL) 23 June 1992 * claims 1-20; figure 2 *	1	G21C3/10 B23K9/167
A	FR 2 625 022 A (FRAMATOME SA ;COGEMA (FR)) 23 June 1989 * pages 1-8,14; figure *	1-4	
A	DE 43 14 099 A (BINZEL ALEXANDER GMBH CO KG) 20 October 1994 * claims 1-4; figure 1 *	1	
A	US 3 431 390 A (MANZ AUGUST F) 4 March 1969 * the whole document *	1	
A	FR 2 536 897 A (US ENERGY) 1 June 1984 * abstract *	3	
A	EP 0 483 724 A (WESTINGHOUSE ELECTRIC CORP) 6 May 1992 * abstract; figures 1-7 *	1,3,4	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)
G21C
B23K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	14 July 1997	Deroubaix, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

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Application No.	Ref.	Date
03 776 153.3 - 2208	55678 EP sb/ea	27.10.2006
Applicant: Westinghouse Electric Sweden AB		

Communication pursuant to Article 96(2) EPC

The examination of the above-identified application has revealed that it does not meet the requirements of the European Patent Convention for the reasons enclosed herewith. If the deficiencies indicated are not rectified the application may be refused pursuant to Article 97(1) EPC.

You are invited to file your observations and insofar as the deficiencies are such as to be rectifiable, to correct the indicated deficiencies within a period

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of 4 months

from the notification of this communication, this period being computed in accordance with Rules 78(2) and 83(2) and (4) EPC.

One set of amendments to the description, claims and drawings is to be filed within the said period on separate sheets (Rule 36(1) EPC).

Failure to comply with this invitation in due time will result in the application being deemed to be withdrawn (Article 96(3) EPC).

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Zanotti, Laura
Primary Examiner
for the Examining Division

Enclosure(s): 5 page/s reasons (Form 2906)

Registered Letter
EPO Form 2001 07.02CSX

The examination is being carried out on the **following application documents**:

Description, Pages

1-16 as published

Claims, Numbers

1-14 as published

Drawings, Sheets

1/5-5/5 as published

1. The following documents are referred to in this communication:

D1: US-A-4 609 524
D2: US 2001 019 597 A1

Furthermore, the following documents are cited by the examiner (see the Guidelines, C-VI, 8.7). A copy of the documents is annexed to the communication.

D3: EP 0 566 862 A1
D4: EP 0 869 512 A1

2. Independent claims

2.1. Claims 1 and 12

Document D1, which is considered to represent the closest state of the art, discloses a nuclear fuel rod (1) comprising a cladding tube (2), that defines a closed inner space (5) and which is manufactured from a zirconium based alloy, such as Zircaloy (col. 2, lines 38-39), a pile of nuclear fuel pellets (6), arranged in the inner space in the cladding tube so that the pellets fill part of the inner space, and a fill gas (8) arranged in the closed inner space in order to fill the rest of the inner space. D1 discloses that the fill gas contains a major proportion of helium with the addition of a minor proportion of carbon monoxide (col. 3, lines 19-24), which corresponds to an amount of 2-3 percent by volume based on the volume of the helium.

The subject-matter of claims 1 and 12 therefore differs from this known nuclear fuel rod in that:
a) the internal pressure of the fill gas in the BWR fuel rod amounts to at least 2 bar at room temperature;
b) the proportion of carbon monoxide is at least 3 volume per cent of the fill gas.

Feature a) solves the specific problem of obtaining a reasonable internal pressure during operational conditions. This specific problem is independent from the kind of gas which fills the internal space.

Feature b) solves another specific problem, namely the prevention of secondary hydrogenation by means of the adsorption of CO on the zirconium surface of the fuel rod cladding.

Hence the functional interaction between features a) and b) does not produce a synergistic effect which is different from the sum of the technical effect of each individual feature.

Therefore, for assessing inventive step, claims 1 and 12 have to be considered as defining a juxtaposition of features, and not a combination (see Guidelines C-IV, 9.5).

It is well known in the art that the internal pressure of the fill gas in a BWR fuel rod is higher than 2 bar (see for example document D3, col. 4, lines 14-15 which indicates a pressure of 60 psi = 4, 137 bar or document D4, col. 2, lines 15-18, which indicates a pressure of 10 at = 9.8 bar) and is calculated taking into account the pressure in

operational condition (see D3, col. 4, lines 3-6). Therefore, feature a) does not appear to provide any contribution to an inventive activity.

Feature b) defines a lower limit for the amount of CO in the fill gas. However, this lower limit does not appear to have a specific technical effect if compared to the amount disclosed in the prior art.

Firstly, it has to be noted that from the disclosure of D1, since the major portion of the gas filling the space is helium and no other gases fill the space, it can be derived that the amount of 2-3 percent by volume based on the volume of the helium is almost the amount of 2-3 percent by volume based on the total volume of the fill gas. Hence, the amount of CO disclosed in D1 is very close to the one defined in claims 1 and 12.

Secondly, there is in the application no explanation for this specific lower limit of 3 per cent. On the contrary, it is stated in the description, page 6, lines 1-4, that even a smaller fraction of CO strongly reduces the hydrogen absorption speed. This is also confirmed on page 6, lines 24-25, where it is stated that the proportion of CO is at least 2 volume per cent.

The effect of CO adsorption appears to depend on a minor amount of CO in the fill gas, and not on the particular value of 3 per cent. Therefore, the choice of 3 per cent claimed in claims 1 and 12 appears to be an arbitrary selection of a value which is not explicitly disclosed in the prior art, but which also does not provide a specific technical contribution.

Therefore, the subject-matter of claim 1 and 12 does not involve an inventive step in the sense of Article 56 EPC.

2.2. Independent claims 5 and 13

Document D1 is considered to represent the closest state of the art also for claims 5 and 13. D1 discloses all the features of the preamble of claim 5, as already explained for claim 1.

Furthermore, D1 also discloses that the proportion of CO is almost the amount of 2-3

percent by volume based on the total volume of the fill gas. The claimed range of at least 2 volume per cent of fill gas therefore includes the disclosed range and is not novel.

The subject-matter of claims 5 and 13 differs from the known nuclear fuel rod only in that the internal pressure of the fill gas in the PWR fuel rod amounts to at least 10 bar at room temperature.

It is well known in the art that the internal pressure of the fill gas in a BWR fuel rod is higher than 10 bar (see for example document D3, col. 4, lines 13-14, which indicates a pressure of 390 psi = 26.9 bar or document D4, col. 2, lines 15-18, which indicates a pressure of 30 at = 29.42 bar) and is calculated taking into account the pressure in operational condition. Therefore, this feature does not appear to provide any contribution to an inventive activity and the subject-matter of claims 5 and 13 does not involve an inventive step.

2.3. Independent claim 11

It is well known in the art that the single fuel rods are assembled to constitute a fuel assembly. Therefore, the subject-matter of claim 11 does not involve an inventive step for the same reasons set forth for claims 1 and 5.

3. Dependent claims

As for claims 1 and 5, the lower limit of the proportion of CO defined in claims 2-4 and 6-8 appear to be only an arbitrary selection of values which does not provide any specific technical contribution.

The additional features of claims 9 and 14 are already disclosed in document D2 (see abstract mentioning the zirconium oxide internal coating) and the additional feature of claim 10 is disclosed in D1 (helium as fill gas).

Therefore, the subject-matter of claims 2-4 and 6-10 and 14 does not involve an inventive step.

4. It is not at present apparent in which combination of features the applicant perceives an inventive concept. The applicant is therefore invited, in his letter of reply, to provide arguments concerning the inventive concept he is looking to protect. New claims must be drafted expressing the inventive concept and taking into account the above comments. The description should be brought into conformity with these claims.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 93 10 4164

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	EP-A-0 018 290 (FRAMATOME) * page 6, line 27 - page 7, line 24; figures 4-6 * * page 9, line 32 - line 34 *	1,2,5,9	G21C17/07 G21C17/06 G01L1/25
A	EP-A-0 082 102 (KRAUTKRÄMER GMBH) * page 3, line 24 - page 4, line 4; figures 1-4 * * page 5, line 14 - line 27 *	1,9	
A	EP-A-0 115 231 (FRAGEMA) * page 8, line 33 - page 10, line 27; figures 1-3,6,7,10 *	1,3,4,5,7,9	
A	EP-A-0 229 837 (HITACHI CONSTRUCTION MACHINERY CO.) * page 30, line 4 - page 31, line 14; figure 4 *	1,9	
A,D	EP-A-0 178 860 (EXXON NUCLEAR COMPANY INC.) * page 2, paragraph 1 * * page 8 - page 9; figures 2,4,6 *	1,6,9	TECHNICAL FIELDS SEARCHED (Int. Cl.5) G21C G01L
A	MESURES REGULATION AUTOMATISME vol. 46, no. 5, May 1981, PARIS FR pages 63 - 67 A. MADELAINE 'Détermination des contraintes superficielles par mesure de la vitesse de propagation d'ondes de Rayleigh' * the whole document *	1,9	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	12 JULY 1993	JANDL F.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document